AUTO-VACUUM REFRIGERATING MACHINE

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

1916

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Capacity and efficiency test
of an autovacuum

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CAPACITY AND EFFICIENCY TEST OF AN

AUTOVACUUM REFRIGERATING MACHINE

A THESIS

PRESENTED BY

FREDERIC PAUL STRAUCH
WILBUR HERRING ARMACOST

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

MAY 25, 1916

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ACKNOWLEDGMENTS

The writers are greatly indebted to Professor E. S. Libby, for his assistance and advice in the construction and installation of the machine, and to Mr. W. J. Kelly, of the Autovacuum Refrigerating Company.

They also wish to express their thanks, and appreciation for the help received from the various Shop Instructors and Assistants.

PREFACE

The following pages give the results of an efficiency and capacity test of an Autovacuum Refrigeration Machine under various rates of expansion and boiling.

The patents of this machine were issued to the Autovacuum Refrigerating Co. of Louisiana in December of 1914.

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PART I.

DESCRIPTION OF APPARATUS.

Description of Apparatus.

The apparatus and connections are shown in the diagrammatic outline in Figure I.

The machine consists of three tanks, two horizontal and one vertical. The two horizontal tanks AA, shown in Figure I. constitute the generator and absorber. The vertical tank B, is the combined condenser and receiver.

The two horizontal tanks are connected by two pipes, a short one "a" called the up-flow, and the other "b", called the down-flow. The down-flow pipe reaches almost to the bottom of the lower tank. The circulation of the liquor takes place through these pipes between the tanks. There is a twelve inch gauge glass on each tank. The upper tank contains a cooling coil in which the cold water is circulated. The flow of water enters through, and is regulated, by valves "M". A large pipe "F" leads from the top of the generator and connects to the line into the condenser "B". This pipe "F" acts as a dehydrator or rect-

ifier, the function of which is to separate entrained water from the ammonia gas. A large cross-fitting provides connection for the ammonia pressure and vacuum gauge "D", and for safety valve "S", also for purge valve "P".

The line from the dehydrator leads through stop-valve "H" to the combined condenser and receiver "B".

The combined condenser and receiver "B" has a double coil running through it; a one-half inch pipe coil inside of a one inch pipe. The two coils have separate end connections. The outside coil is for water and the flow is regulated by valve "M". The one-half inch coil is for the ammonia, the coil ending in the tank at the bottom.

An ammonia outlet is provided at the bottom of the tank and is connected to the line leading to the refrigerating coils. A sampling valve connected to a tee is placed in this line near the outlet of the receiver.

The ammonia line leads from the receiver "B" through expansion valve "E" to the bottom row

refrigerating coils "J". The return line from the top of the refrigerating coils leads down behind, and enters into, lower tank "A" through the return valve "R". A sampling valve is placed in the return line between the return valve and the generator.

A gas burner "L" is placed under the generator as shown. This burner is connected to the gas line through a meter, for measuring the quantity of gas consumed.

The water lines from the generator and receiver are run to separate weighing tanks. Thermometers and thermometer cups are placed in the lines for measuring the temperature of inlet and outlet water.

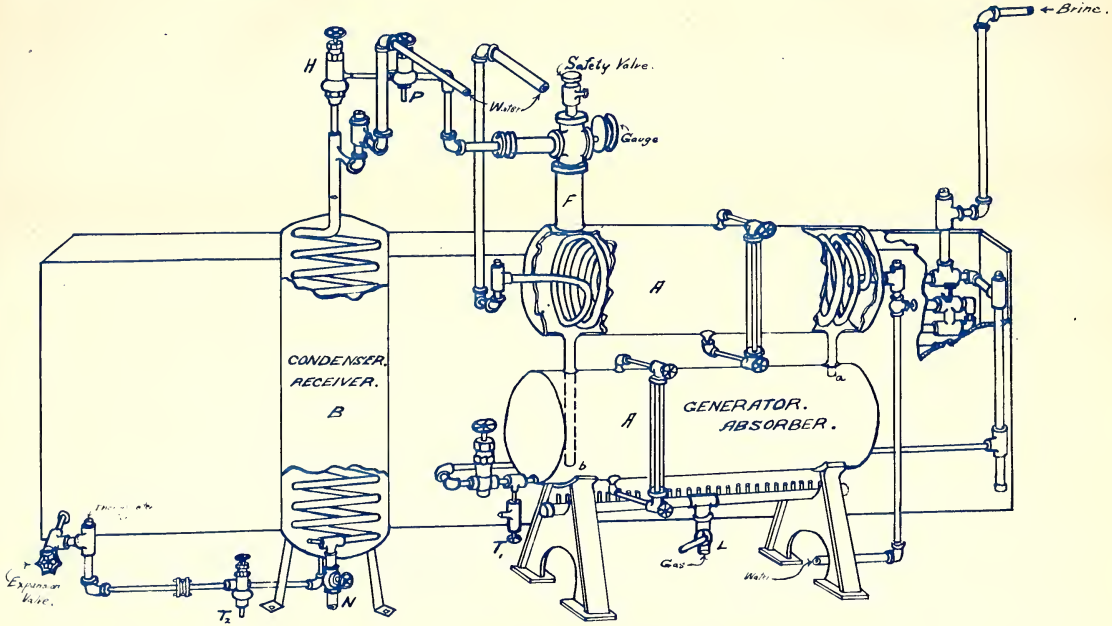
The refrigerating coils are double pipe coils in which ammonia expands in the inside coil, and brine is circulated through the outside coil. The brine is drawn from a small tank about six feet above the top of the coils. The brine is drawn from one of two large tanks on floor level and is pumped by a motor driven centrifugal

pump into the small tank above.

This small tank is provided with an overflow sothat there is always a constant head on the brine flowing through the coils. The outlet is at the bottom of the small tank.

The brine circulates through coils and then passes out at the bottom to a pipe line leading into a weighing tank. Two pet cocks are placed at the outlet of pipe line, by means of which the flow of brine through coils can be regulated.

The coils were boxed in and packed very tight with cork insulation. Thermometer cups and thermometers were placed at inlet and outlet of brine coils.



DIAGRAMMATIC OUTLINE
OF
MACHINE.
Fig. I.

F.P.STRAUCH
N.H.ARMACOST.

PART II.

INSTALLATION.

Installation

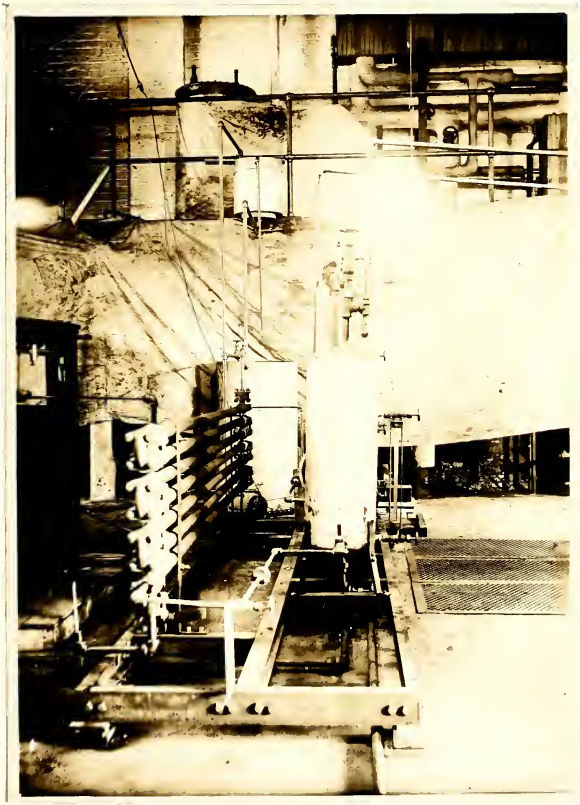
The base of the machine is built of four-inch channel iron and four-inch eye beams; supported at the four corners by large castors, so that the apparatus may be moved about conveniently when not in use. The base is rectangular and is twelve feet long and three and one-half feet wide. The flanges of the end pieces were cut off so that the web of the end pieces would make a snug fit into the side pieces. A four-inch eye-beam is located centrally between the two ends. The refrigerating coil box is supported on five brackets which straddle the central and side beams. The condenser and generator are supported by eye-beams connected between the one side and central beam of base.

The legs of the generator and absorber are made of cast-iron and are fastened by bolts to the eye-beams.

The old piping was all taken out and replaced by extra heavy ammonia pipes and the arrangement of connections, samplers, and thermometer cups

were changed. In order to insure pipe joints being tight a mixture of litharge and glycerine was used on the ammonia fittings and graphite was used on the water fittings.

No. 2.



PART III.

Preliminaries Before Making Final Test.

(A). Charging.

(B). Testing For Leaks.

(C). Purging.

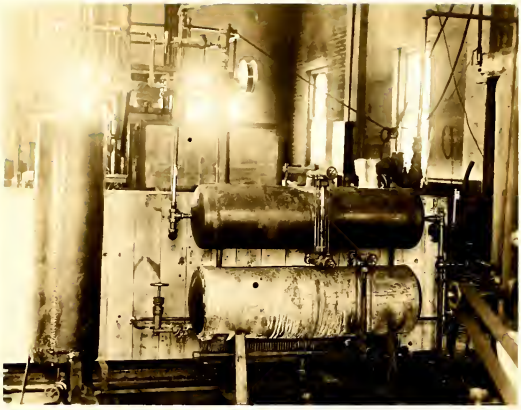
(D). Sampling For Strength.

A.

CHARGING

By charging is meant the filling of the absorber and generator tanks with aqua-ammonia. The lower tank is filled full and the upper tank is about three-quarters full. The connection of the upper gauge glass to the top tank was removed and the liquor was poured in through a funnel. After gauge glass fittings were tightened up we found it necessary to add more ammonia and this liquor had to be drawn in by getting a vacuum on the machine. Getting a vacuum on the machine is explained in detail in the following pages.

No. 3.

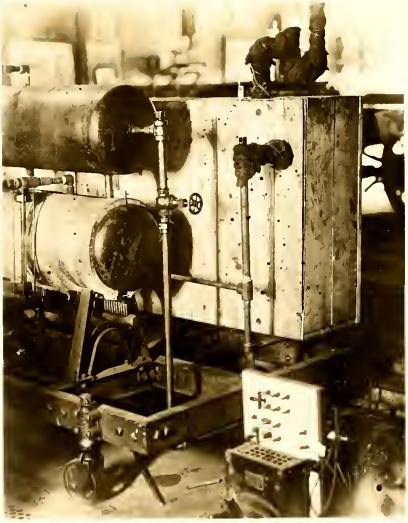


B.

TESTING FOR LEAKS

After all connections were applied with litharge and tightened up, the machine and piping could be tested for leaks. The gas burner was lighted under the generator and absorber and the ammonia was boiled until a reading of about fifty-five pounds was obtained on the pressure gauge. This ammonia was sent through the system on that pressure by opening all the valves. If the leak was very bad you could easily detect it by the strong odor of ammonia gas issuing through the opening. If the leak is very small, as shown by a small drop of pressure on the pressure gauge, other methods of locating the leak must be used. One method we used, was to pass a lighted sulphur wick around all joints and connections and the leak can be detected by the white fumes which issue due to the uniting chemically of the ammonia and sulphur dioxide gases.

No. 4.

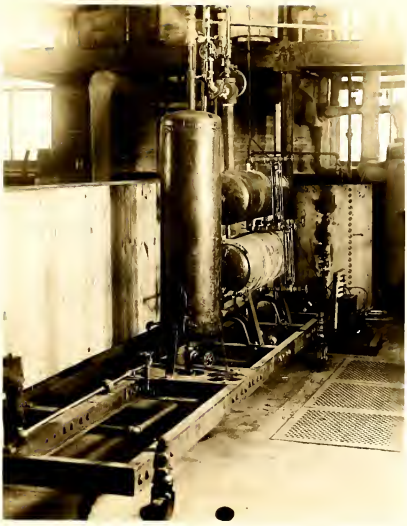


C.

PURGING

The system must be free from air, to get maximum efficiency. The proper time to get the air out is when the gauge shows some pressure just before it is time to boil off. Connect a piece of hose to purge valve, drop the free end into a bucket of water, then open purge valve slightly. The air will pass into the water, forming bubbles. If there are no bubbles, or only a few small ones, the apparatus is free of air. Purging need only be done when pressure is shown on the gauge at the end of the absorption period or when the liquor is all back in the generator-absorber as indicated by the height of liquor in upper gauge glass.

No. 5.



D.

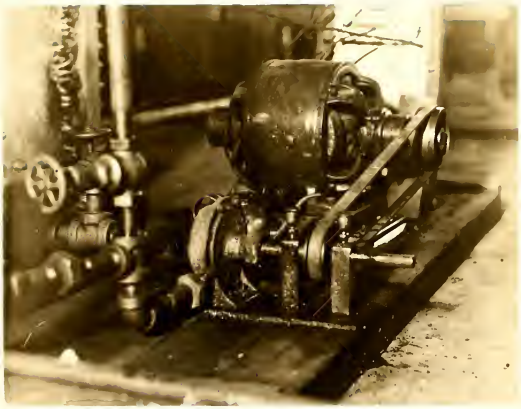
SAMPLING FOR STRENGTH

Boil to about a four or five pound pressure gauge reading and fill up sampling tube, through sampling valve on the lower tank of generator and absorber. Cool this liquor in sampling tube to sixty degrees Fahrenheit and insert Beaume Hydrometer scale, and note reading.

As commercial aqua-ammonia is only twenty-six degrees Beaume, it will be found advantageous to charge machine fully with this and after boiling off thoroughly draw off through sampling valve such an amount of weak liquor as may be necessary, and put in sufficient twenty-six to bring the strength up to twenty-eight.

It will do as good refrigeration with twenty-six as it will with twenty-eight but it will not do as much. The apparatus gives the greatest efficiency when the Beaume scale reading, at sixty degrees Fahrenheit, is twenty-eight degrees Beaume. The brine to be used should be ninety degrees Salometer at sixty degrees Fahrenheit. The brine is a mixture of calcium chloride and water.

No. 6.



PART IV.

METHOD OF OPERATION

Method of Operation.

With the preliminaries finished we are now ready to operate the machine. See that all valves are closed tight. Light gas burner under generator and absorber. When pressure shows seventy pounds on pressure gauge crack the valve leading into receiver-condenser for a minute or two, then continue to open it very slowly, otherwise the liquid may syphon over from top of absorber and generator tanks in the receiver. When pressure shows one hundred pounds on gauge, slowly open water valve into condenser. The pressure gauge reading should never be allowed to go higher than two hundred and twenty-five pounds. The pressure is regulated by the quantity of heat and water used. When the liquid is boiled down to a predetermined mark on the gauge glass the heat should be shut off and the water valve, and valve leading into the condenser closed.

As soon as the heat is shut off, open the water supply valve to top generator tank slowly, allowing a gradual supply of water to flow

No. 7.

through the cooling coils; this will quickly create a vacuum. Continue until gauge shows about twenty-nine inches of vacuum.

Start centrifugal pump and regulate same so that there is a constant head of brine flowing through refrigeration coils. Open return valve, valve leading out of refrigeration coils into lower generator tank, slowly, allowing ab-sorber to create a vacuum in refrigeration coils. Return valve connects refrigeration coils with vacuum tank. After a vacuum is created in the entire system crack the expansion valve leading into refrigeration coils, then continue to open it very slowly until it is one full turn. The amount the expansion valve is to be opened is predetermined by experiment. The rate of flowing of brine, the inches of vacuum and the boiling pressure determine the number of turns the expansion valve is to be opened.

PART V.

TESTS

(A) Preliminary Tests.

(B) Refrigeration Tests.

A.

Preliminary Tests.

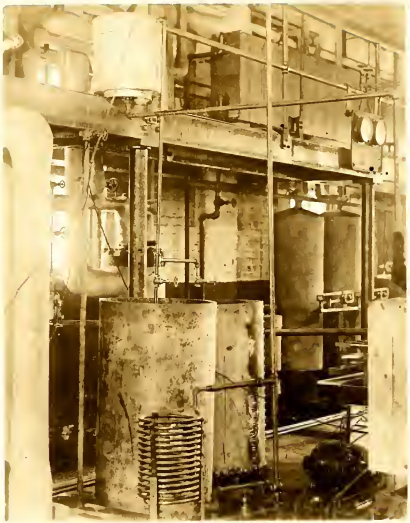
The preliminary tests are made in order that the operator may familiarize himself with the working of the machine.

The centrifugal pump must be run at various speeds to determine the speed at which the rate of flow of brine will keep the small gravity tank full.

Tests were made to determine the amount of water needed to cool the condenser, and also the amount required to cool the generator tank and get vacuum.

The cracking of expansion valve and the amount it had to be opened was approximately determined. After the approximate position is determined, the valve must be opened or closed slightly, as the case may be, so that the temperature of the ammonia as it leaves the refrigeration coils is practically constant. This temperature is also 30 degrees Fahrenheit.

No. 8.



B.

Refrigeration Tests.

The calcium chloride brine was tested and found to be one hundred and four degrees Salometer. The specific heat of calcium chloride brine of one hundred and four degrees salometer is 1.219 at 60 degrees F., and a specific heat of 0.799 as given in Siebels book of Refrigeration. The freezing point of this brine is -17. degrees Fahrenheit. The inlet and outlet brine thermometers were compared and found to read the same within a very small fraction of a degree, that is, within the limits of error of other measurements.

In the first test the rate of flow of brine was kept constant and the opening of the expansion valve was varied to keep the temperature of the ammonia around thirty degrees Fahrenheit, as it left the refrigeration coils. This test was of ten hours and fifty minutes

duration.

The second actual refrigeration test was of eleven hours and twenty minutes duration. The rate of flow of brine was increased by opening pet cock wider. The expansion valve was varied, as in first test, for the first six hours and kept constant for the last five hours.

In the third test the expansion valve was kept constant, at three-eights of a turn, and the rate of flow of brine was twice that of the second test. This run was of four hours and ten minutes duration. This test was made short by increasing the rate of flow of brine.

PART VI.

Discussion and Conclusion.

Discussion and Conclusion.

We found that the best rate of flow of the calcium chloride brine was about one and one-half pounds per minute. This rate of flow was obtained by opening one of the pet cocks about three-eights of a turn.

The greatest amount of refrigeration was obtained by setting the expansion valve at about three-eights of a turn and kept constant throughout the test. The expansion valve should be moved at frequent intervals to prevent it from being clogged up by oil or sediment and then set back again at the three-eights mark. By placing the ear near the expansion valve you can easily detect, by the sound whether or not the valve seat is clear and the ammonia is expanding.

When we varied the opening of the expansion valve, and tried to keep the outlet temperature of the ammonia from the refrigeration coils around thirty degrees, considerable

trouble was experienced in regulating the value due to the fact that the variation in temperature was so great at each fraction of a turn.

From the curves and data we find that this machine gave the largest amount of refrigeration at very slow expansion. We tried various rates of expansion, and as test No. 2 shows, the best capacity was obtained from a very slow expansion.

The mean temperature difference of the brine was obtained as follows: Integrate the curves and divide areas, in square inches, by the length in inches to get the mean ordinate of each curve. The difference between the two mean ordinates, measured according to the temperature scale used, gives the mean temperature difference.

PART VII.

Calculations.

Calculations:

$144W = ws\ (t - t)$

$W = ws\ (t - t)/144$

where, 144 latent heat of ice.

w specific heat of brine.

(t -t) difference in temperature of brine

W capacity of machine in # of ice.

from and at 32 degrees F.

Preliminary Tests

1. W 318 x .799 x 31.5/144 55.5 lbs.

2. W 596 x .799 x 33.0/144 109 lbs.

Test # 1.

W 1144 x .799x30 /144 190 lbs.

Test # 2.

W 887 x .799 x 41.5/144 204 lbs.

Test # 3.

W 1399 x .799 x 19.5/144 151 lbs.

PART VIII.

Data and Curves.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Autovacuum Refrigeration Machine Date May, '16.

Preliminaries:

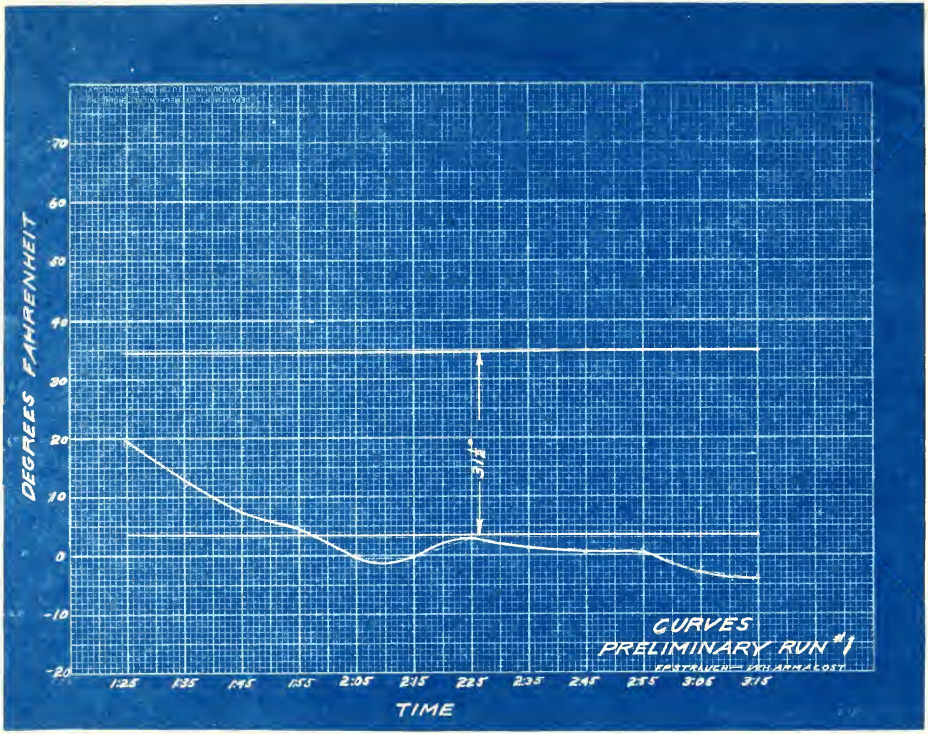
Observer

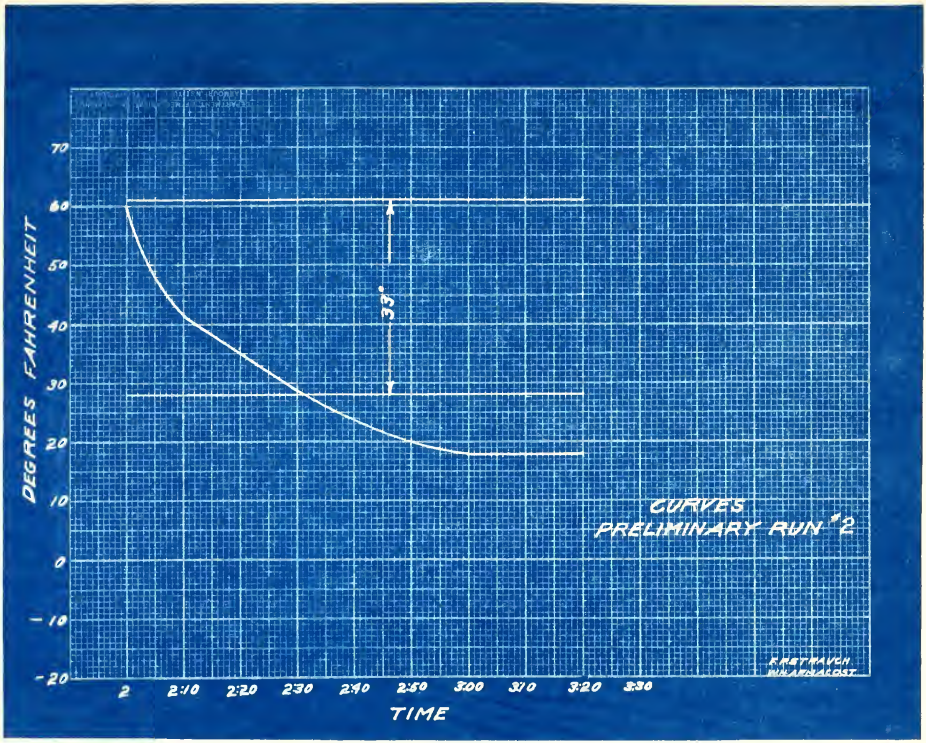
Preliminary No. 1.

Time:	Expansion Brine. Inlet	Expansion Brine. Outlet	Temperatures. Ammonia. Inlet	Temperatures. Ammonia. Outlet.
1:35	62	39	57	58
1:45	69	15	57	34
1:55	69	9	58	19
2:05	69	−1	58	44
2:15	69	−1	50	55
2:25	69	+6	45	62
2:35	69.5	2	60	53
2:45	69.8	1	60	46
2:55	70.0	1	60	24
3:05	70.0	−6	60	42.5
3:15	70.0	−8	60	29.0

Preliminary No. 2.

Time:	Expansion Brine. Inlet	Expansion Brine. Outlet	Temperatures. Ammonia. Inlet	Temperatures. Ammonia. Outlet
2 P.M	61.8	60	60	52
2:10	61.8	42	61.5	46
2:20	61.8	36	62.	43
2:30	61.0	29	62.	37
2:40	61	24	62.	36
2:50	61	20	61.	38
3:00	61	18	60.5	38
3:10	61.4	18	60.0	39
3:20	61.4	18	58.1	40
3:30	61.4	18	58.0	40.5


DEGREES FAHRENHEIT
70
60
50
40
30
20
10
0
-10
-20
1:25
1:35
1:45
1:55
2:05
2:15
2:25
2:35
2:45
2:55
3:06
3:15
TIME
CURVES
PRELIMINARY RUN #1
EXTRUDER — PATH AMMCO ST.


DEGREES FAHRENHEIT
70
60
50
40
30
20
10
0
-10
-20
33°
2
2:10
2:20
2:30
2:40
2:50
3:00
3:10
3:20
3:30
TIME
CURVES
PRELIMINARY RUN #2
EASTMAN
KODAK COMPANY

Log Test No. I.

Ammonia Strength 25.5 degrees Beaume.

Calcium Chloride Brine Strength 104 Salometer.

10:45 A.M. Gas lighted under generator.

11:13 A.M. Valve opened to condenser at ammonia pressure of 75 lbs.

11:16 A.M. Water turned into cooling coils of condenser at ammonia pressure of 80 #.

12:31 P.M. Gas turned off.
Water turned into cooling coils of absorber and generator
Water turned off at condenser.

1400# Weight of water necessary to condense ammonia gas.

3277# Weight of water necessary to obtain vacuum of 29" mercury.

270 Cu. ft. of gas consumed.

Test of Autovacuum Refrigeration Machine Date May 5/16.

Thesis Test No. I.

Observer Expansion Temperatures:

	Time	Brine Inlet	Brine Outlet	Ammonia Inlet	Ammonia Outlet
P.M.	1:55	66	58	61	52
	2:00	65	54	56	20
	2:05	65	55	56	18
	2:10	65	54	56	30
	2:15	65	55	57	40
	2:20	60	52	55	27
	2:30	65	51	55	34
	2:40	65	53	57	49
	2:50	65	50	56	35
	3:00	65	52	56	26
	3:10	65	51	57	25
	3:20	65	52	57	35
	3:30	60	54	57	29
	3:40	59	45	58	28
	3:50	59	22	58	29
	4:00	59	28	58	30
	4:10	59	25	58	32
	4:20	59	27	58	30
	4:30	59	28	59	25
	4:40	59	28	59	25
	4:50	59	29	59	22
	5:00	59	31	59	19
	5:10	60	31	59	19
	5:20	60	31	59	24
	5:30	60	30	59	29
A.M.	8:15	61	60	56	32
	8:25	61	58	54	37
	8:35	61	52	52	43
	8:45	61	51	54	47
	9:05	61	51	55	49
	9:15	61	47	57	50
	9:25	61	35	61	50
	9:35	61	33	61	50
	9:45	61	24	61	35
	9:55	61	18	61	38
	10:05	61	18	61	35
	10:15	61	18	61	33
	10:25	63	20	61	30
	10:35	63	21	61	29
	10:45	63	19	61	30
	10:55	63	19	61	32
	11:05	63	18	61	34
A.M.	19:15	63	17	61	29
	11:25	63	17	61	28
	11:35	63	16	61	27
	11:45	63	16	61	27
	11:55	63	16	61	26
P.M.	12:05	64	16	61	26
	12:15	65	16	61	24
	12:25	65	16	62	25
	12:35	65	16	62	25

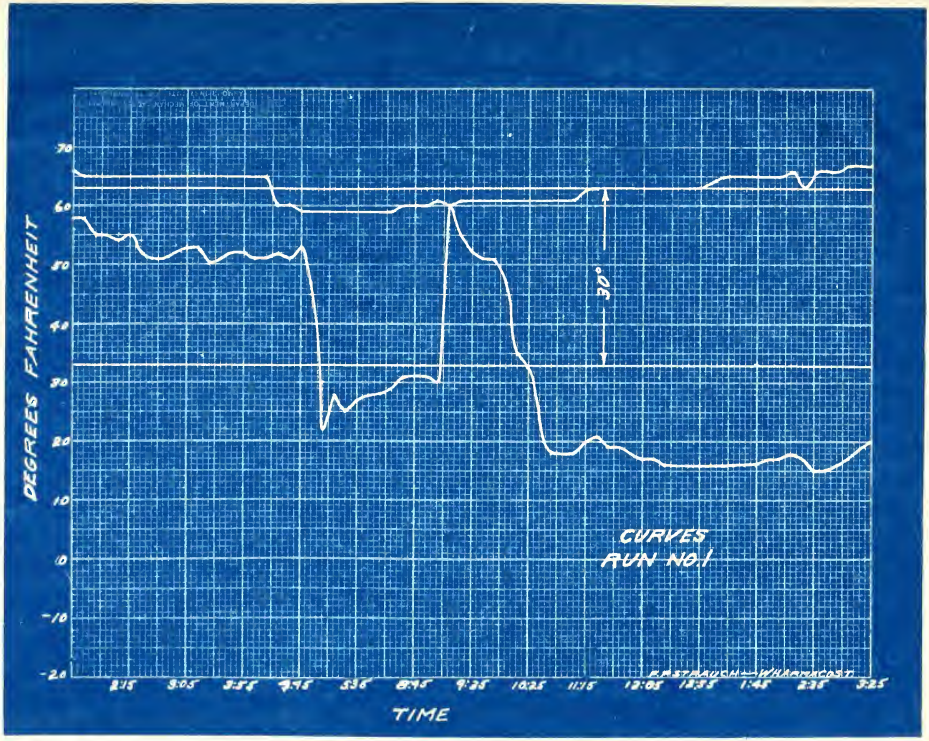
ARMOUR INSTITUTE OF TECHNOLOGY

Test of _____ Date May 16.

Thesis Test No. I. (Continued)

Observer _____ Expansion Temperatures.

Time	Brine Inlet	Brine Outlet	Ammonia Inlet	Ammonia Outlet
12:35	65	16	62	24
12:45	65	16	62	26
12:53	65	17	62	26
1:05	66	17	62	24
1:15	63	18	62	25
1:25	66	17	62	24
1:35	66	15	62	34
1:45	66	15	63	36
1:55	66	16	63	38
2:05	67	16	63	38
2:15	67	17	63	38
2:25	67	18	63	37
2:35	67	19	63	38
2:45	67	19	62	41
2:55	67	19	57	48
3:05	66	19	56	58


DEGREES FAHRENHEIT
70
60
50
40
30
20
10
0
-10
-20
30°
CURVES
RUN NO.1
8:15
9:05
9:55
4:45
5:36
8:45
9:35
10:25
11:15
12:05
12:55
1:45
2:35
3:25
TIME
P.M. STRAUCH — WHANNCOST

Log Test No. II.

Ammonia Strength 25.0 degrees Beaume

Calcium Chloride Brine Strength 104 Salometer

3:35 P.M. Gas lighted under generator

4:10 P.M. Valve opened to condenser at ammonia pressure of 75 lbs.

4:11 P.M. Water turned into cooling coils of condenser at ammonia pressure of 80#.

5:35 P.M. Gas turned off.
Water turned into cooling coils of absorber and generator.
Water turned off at condenser.

. 3172# Wight of water necessary to condense ammonia gas.
Vacuum was obtained by standing over night.

340 Cu. ft. of gas consumed.

Test of _____ Date _____

Thesis Test No. 2. (Continued)

Observer _____ Expansion Temperatures:

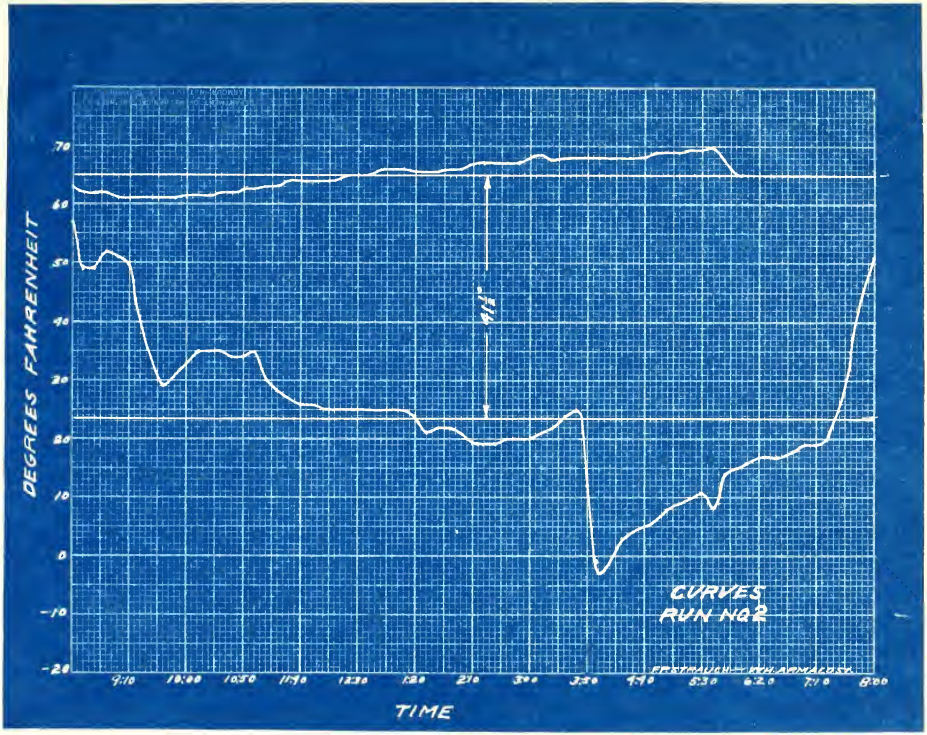
Time	Brine Inlet	Brine Outlet	Ammonia Inlet	Ammonia Outlet
5:10	69	9	65	58
5:20	69.5	10	65	58
5:30	69	11	65	59
5:40	70	10	65	59
5:50	67	14	65	59
6:00	65	15	65	59
6:10	65	16	65	59
6:20	65	17	65	58
6:30	65	17	65	58
6:40	66	17	65	58
6:50	66	18	65	59
7:00	66	19	65	59
7:10	66	19	65	59.5
7:20	66	20	64.5	61
7:30	66	35	63	66
7:40	66	51	59	67
7:45	66	56	58	68

Test of Autovacuum Refrigeration Machine Date May, 16.

Thesis Test No. R.

Observer Expansion Temperatures.

	Time	Brine Inlet	Brine Outlet	Ammonia Inlet	Ammonia Outlet
A.M.	8:40	63	54	60	20
	8:50	62	49	60	19
	9:00	61	51	61	31
	9:10	61	50	61	20
	9:20	61	41	61	35
	9:30	61	34	61	45
	9:40	61	29	61	42
	9:50	61	31	61	30
	10:00	61	35	61	24
	10:10	61.5	35	61	20
	10:20	61.5	35	61	18
	10:30	61.5	35	61	20
	10:40	62	35	61	27
	10:50	62	34	61	24
	11:00	62.5	34	62	33
	11:10	62.5	33	62.5	26
	11:20	63	30	62.5	32
	11:30	63	28	62	31
	11:40	64	26	62	24
	11:50	64	26	62	23
	12:00	64	25	62	20
	12:05	64	25	63	26
	12:20	65	25	63	23
	12:30	65	25	63	23
	12:40	65	25	63	23
	12:50	66	25	63	23
	12:60	66	25	64	16
	1:10	66	25	64	17
	1:20	66.5	25	64	20
	1:30	66	25	64	18
	1:40	66.5	29	64	16
	1:50	66	21	64	19
	2:00	66	22	64	22
	2:10	67	21	64	38
	2:20	67	19	64	38
	2:30	67	19	64	30
	2:40	67	20	64	35
	2:50	67	20	64	35
	3:00	68	20	64	30
	3:10	68.5	21	64	26
	3:20	68.0	22	65	30
	3:30	67.5	24	65	25
	3:40	68	25	65	23
	3:50	68	12	65	46
	4:00	68	-3	65	58
	4:10	68	-1	65	53
	4:20	68	+3	65	55
	4:30	68	4	65	53
	4:40	68	5	65	58
	4:50	68	6	65	58
	5:00	69	8	65	59


DEGREES FAHRENHEIT
70
60
50
40
30
20
10
0
-10
-20
41°
9:10
10:20
10:50
11:40
12:30
1:20
2:10
3:00
3:50
4:40
5:30
6:20
7:10
8:00
TIME
CURVES
RUN NO 2

Log Test No. III.

Ammonia Strength 25 degrees Beaume.

Calcium Chloride Brine Strength 104 Salometer.

10:40 P.M. Gas lighted under generator.

10:50 P.M. Valve opened to condenser at ammonia pressure of 75 lbs.

10:52 P.M. Water turned into cooling coils of condenser at ammonia pressure of 80#.

12:10 A.M. Gas turned off.
Water turned into cooling coils of absorber and generator.
Water turned off at condenser.

2054# Weight of water necessary to condense ammonia gas.

1230# Weight of water necessary to obtain vacuum of 29" mercury.

300 cu.ft. of gas consumed.

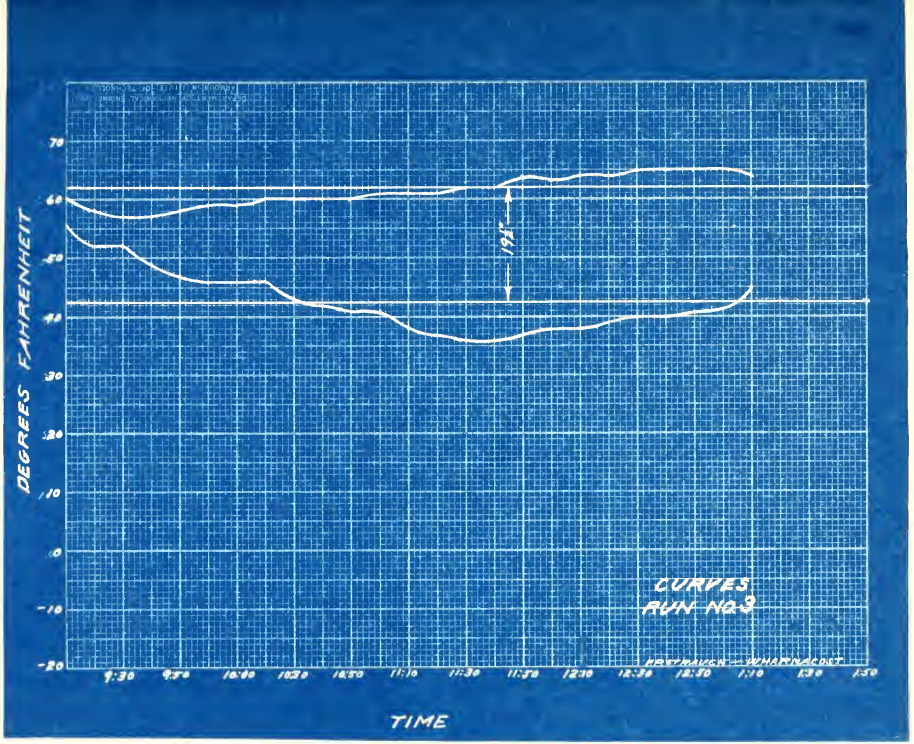
Test of AUTOVACUUM REFRIGERATION MACHINE Date MAY-1916

THESIS TEST NO 3

Observer

TEMPERATURES.

TIME	EXPANSION BRINE INLET	EXPANSION BRINE OUTLET	AMMONIA TEMP'S AMMONIA INLET	AMMONIA OUTLET																
9:20	60	55.5	63	36			11:60	63	38	69	33									
9:25	58	52	62.5	35			12:10	69	38	69	38									
9:30	57	52	63	90			12:20	69	39	69	39									
9:40	57	49	62	39			12:30	65	90	65	35									
9:50	58	47	62	38			12:40	65	99	65	38									
10:00	59	96	62	38			12:50	65	41	65	40									
10:10	59	46	63	39			1:00	65	41	65	39									
10:20	60	46	63	39			1:10	69	95	69	50									
10:30	60	93	63	39																
10:40	60	41	63	38																
10:50	61	41	63	33																
11:00	61	38	64	32																
11:10	62	36	64	25																
11:20	62	36	64	27																
11:30	62	36	69	25																
11:40	62	36	64	27																
11:50	69	37	69	38																


DEGREES FAHRENHEIT
70
60
50
40
30
20
10
0
-10
-20
15°
9:30
9:50
10:00
10:20
10:50
11:10
11:30
11:50
12:10
12:30
12:50
1:10
1:30
1:50
TIME
CURVES
RUN NO. 3
WESTWARD — WHARTON CREST